DOCUMENT RESUME

ED 244 617 IR 011 140

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TITLE The Fourth Revolution in Teaching: Meta-Analyses.
PUB DATE Apr 84
NOTE 13p.; Paper presented at the Annual Meeting of the American Educational Research Association (68th, New Orleans, LA, April 23-27, 1984).
PUB TYPE Information Analyses (070) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Academic Achievement; *Computer Assisted Instruction; Computer Managed Instruction; *Individualized Instruction; *Instructional Innovation; Literature Reviews; *Meta Analysis; Programed Instructional Materials; *Programed Tutoring; Research Methodology; Teaching Methods
IDENTIFIERS *Instructional Effectiveness

ABSTRACT

Three major educational revolutions have been the advent of writing, the use of books as teaching tools, and the shift in educational responsibility from the home to the school. The fourth revolution, which is based on the use of electronic technology in teaching, began with programmed teaching machines, individualized instruction, and the development of computer based education. This paper draws on meta-analyses conducted at the University of Michigan and the University of Colorado to review what has been learned from the application of educational evaluation and research synthesis tools to the area of instructional technology. Eight separate meta-analyses are covered, representing at least 500 separate studies. The results presented indicate that programmed instruction was more effective in recent studies than in earlier ones; individualized systems produce about the same results as conventional teaching at the elementary and secondary levels, although at the college level they are strikingly effective; and computer based education has real potential as a tool for improving student achievement. Eight references and four figures are appended. (LMM)

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ED244617

The Fourth Revolution in Teaching: Meta-Analyses

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A symposium paper presented at the annual meeting
Of the American Educational Research Association,
New Orleans, April 1984

IR011140

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At least three major revolutions have swept over education during the past 2000 years. The first occurred many centuries ago when writing began to be used as a tool in teaching, and learners were freed from the task of rote memorization of every point. A second revolution came with the invention of printing and the subsequent use of books as a teaching medium. And the third came when primary responsibility for educating the young was shifted from the home to the school.

We are now witnessing a fourth revolution in education. It is based on the use of electronic technology in teaching, and it has already changed the look of our classrooms. No one is surprised nowadays to find young learners working on arithmetic or language exercises at computer stations in our schools. Nor is it unusual to find school children learning about literature, science, or society from films and videotapes. Older students use language tapes in foreign language courses, and they use records and tapes in music appreciation classes. They analyze physical and social data on computers, and they write reports using word-processing programs.

This fourth revolution in teaching began modestly enough nearly 30 years ago, and its progress has come in three waves. The first wave of interest was generated by B. F. Skinner. In his 1954 article "The Science of Learning and the Art of Teaching," Skinner argued that machines could teach more reliably and effectively than human teachers do, and he described programmed teaching machines of his own design that were already being used in instruction. The programmed machines waited patiently for a learner's response, reinforced the response immediately, and stuck to a carefully crafted script.

The second stage in this revolution was marked by the development of individualized instruction. Like programmed instruction, individualized teaching emphasized independent work, self-pacing, and the achievement of mastery, but it used longer instructional units--often called learning activity packages or modules--and it gave learners more freedom to choose among different instructional means. Individually Prescribed Instruction, Project Plan, Individually Guided Education, and Keller's Personalized System of Instruction are probably the best known of the individualized systems developed during the 1960s.

The third stage in the technological revolution was marked by the development of computer-based education. Computers were first used in education to deliver programmed and individualized instruction, but in recent years, they have been used to do more and more sophisticated teaching

jobs. Some educators are now arguing, in fact, that students learn most from computers when they simply communicate with them in languages the computers understand.

The first three revolutions in education ran their course without help from educational research. No one tried to measure their effects while these revolutions were in progress. No one used statistical methods to predict or influence their outcomes. The revolutions just happened--without measurement, prediction, or control. The fourth revolution is different. It is occurring at a time when we have tools for evaluating specific programs and tools for drawing general conclusions from a collection of specific evaluations. The fourth revolution is occurring at a time when educational measurement, prediction, and control are possible.

The tools of educational evaluation and research synthesis have already been applied to the area of instructional technology, and my purpose this morning is simply to review what we have learned from this work. My account will draw heavily on meta-analyses carried out at the University of Michigan, but it will also cover work done at the University of Colorado. In all, my account will cover eight separate meta-analyses and at least 500 separate studies. To put some order into my review, I will divide it into three parts. First, I'll talk about programmed instruction and its effects on learners. Then, I'll move on to individualized systems and their effects. Finally, I'll look at the effects of computer-based education.

Programmed Instruction

The first meta-analysis of findings in this area was carried out at the University of Colorado in 1977 by Susan Hartley. She located a total of 40 separate studies carried out between 1962 and 1974 in elementary and secondary mathematics classes. In the typical study, achievement test scores of programmed and conventional groups were virtually indistinguishable. They differed by only 0.11 standard deviations. The group mean was at the 50th percentile for the conventional group and at the 54th percentile for the programmed group. The results of Hartley's analysis appear at the left of Figure 1.

Insert Figure 1 about here

Our research team at the University of Michigan also carried out two meta-analyses of findings on programmed instruction, one covering 48 studies at the secondary level and one covering 57 studies at the college level (C.-L. Kulik, Shwalb, & Kulik, 1982; J. Kulik, Cohen, & Ebeling,

1980). Our results are at the middle and right of Figure 1. We found that programmed instruction raised student test scores by 0.08 standard deviations in the typical secondary school application, and by 0.25 standard deviations in the typical college application.

It would be easy enough to dismiss programmed instruction on the basis of these results. They seem to show that programmed instruction has trivial effects in elementary and secondary schools and small ones at the college level. But there is more to programmed instruction than this. As Figure 2 shows, each of the three meta-analyses demonstrated that programmed instruction was more effective in recent studies than in earlier ones. Programmed instruction had a poor record in its earlier years. It has a relatively good record in recent years.

Insert Figure 2 about here

This is certainly a set of findings that needs an explanation. It may be that the art of programming has improved in subtle ways in recent years. It may be that evaluation methodology has improved. Or perhaps the early years gave teachers a sense of what programmed instruction can and cannot do, and they now use it more selectively. I do not know which of these explanations is the right one. I feel confident, however, that meta-analysis will eventually help us choose between such competing explanations.

Insert Figure 3 about here

Individualized Systems

The record of effectiveness of individualized systems of instruction is equally perplexing. Figure 3 gives the overall meta-analytic results. The results at the left on the figure are from Hartley's (1978) meta-analysis on elementary and secondary school findings; the results in the center are from our analysis of secondary school findings (Bangert, Kulik, & Kulik, 1983); and the results at the left are from our analysis of college findings (J. Kulik, Kulik, & Cohen, 1979). The figure shows that individualized systems produce about the same results as conventional teaching at the elementary and secondary levels. At the college level, however, individualized systems are strikingly effective.

What can account for such results? Again, we don't know for sure, but it's possible to speculate.

1. It may be that college learners have the cognitive skills required by individualized instruction and that precollege learners lack these skills. To profit from individualized teaching, learners need to be able to pace themselves, make choices, and work independently. College students are better prepared than precollege learners for such tasks.

2. A second possible explanation is somewhat more complex. Individualized instruction at the college level has been greatly influenced by the work of psychologist Fred Keller and his colleagues. Unlike the individualized systems developed for elementary and secondary schools, Keller's system places great emphasis on the social support provided by peer tutors. It is possible that individualized systems have been successful at the college level because of this unique emphasis on social support.

3. A third possibility must also be investigated. The studies used in the precollege and secondary meta-analyses almost all came from dissertations, whereas the studies at the college level almost all came from journals and books. The results from the different levels of education look more similar when they are reported by publication source (Figure 4).

Insert Figure 4 about here

It is impossible for me to choose right now between these three explanations. I have a hunch about which of the explanations is the correct one, but I have not yet carried out the analyses needed to prove of disprove my hunch. I feel confident, however, that future meta-analyses will clear up the picture.

Insert Figure 5 about here

Computer-Based Education

In contrast to these findings on programmed and individualized instruction, findings on computer-based instruction are relatively straightforward (Hartley, 1977; C.-L. Kulik, Kulik, & Bangert-Drowns, 1984; J. Kulik, Bangert, & Williams, 1983; J. Kulik, Kulik, & Cohen, 1980). Results from four different meta-analyses are rather consistent in showing that computer-based education has real potential as a tool in improving student achievement (Figure

5). The average effect of computer-based teaching was to raise student achievement by approximately 0.4 standard deviations, or from the 50th to the 66th percentile.

Results from computer-based teaching appeared to be slightly stronger at the lower level of instruction than at the higher levels. That is perhaps because programs developed so far exploit the capacities of computers most adapted to lower level learning: their patience in drilling and tutoring students and their capacity to respond immediately and appropriately to student answers. The effectiveness of the computer in college teaching may improve when other capacities of computers are exploited in education.

Conclusion

Both primary evaluation studies and meta-analyses are increasing our understanding of instructional technology--an important force that is now transforming education. Such studies are not only establishing a baseline for evaluating further developments, but they are also pointing to areas where further developmental work needs to be done.

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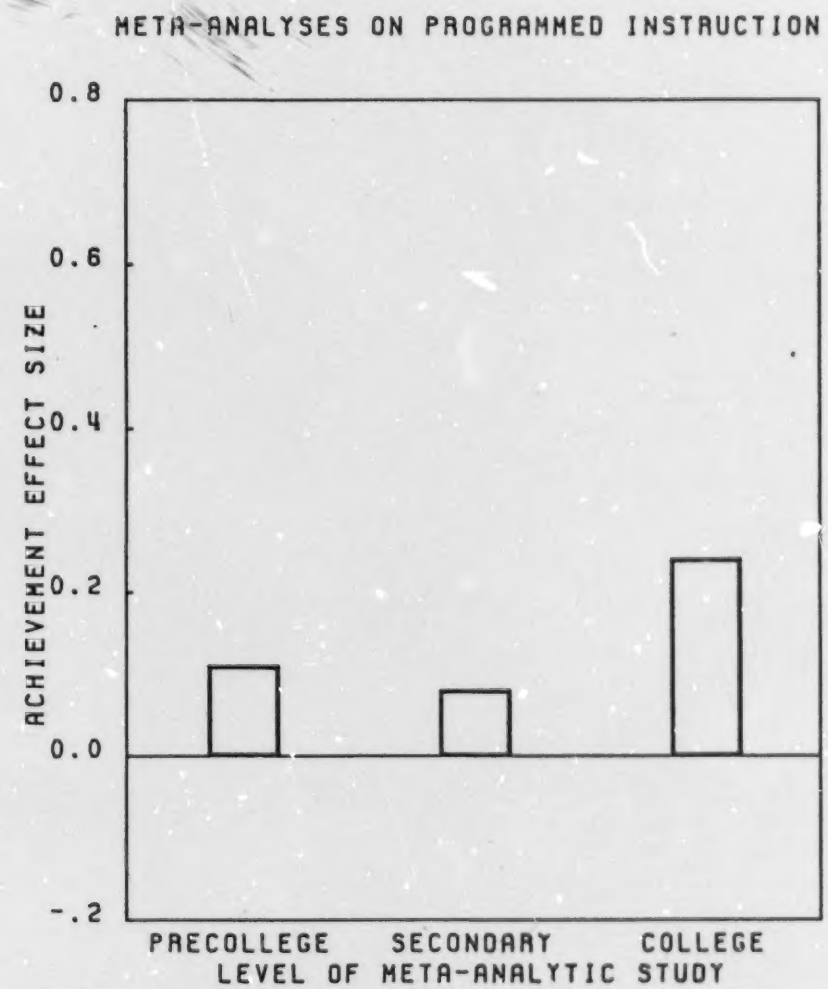
META-ANALYSES ON PROGRAMMED INSTRUCTION
ACHIEVEMENT EFFECT SIZE
0.8
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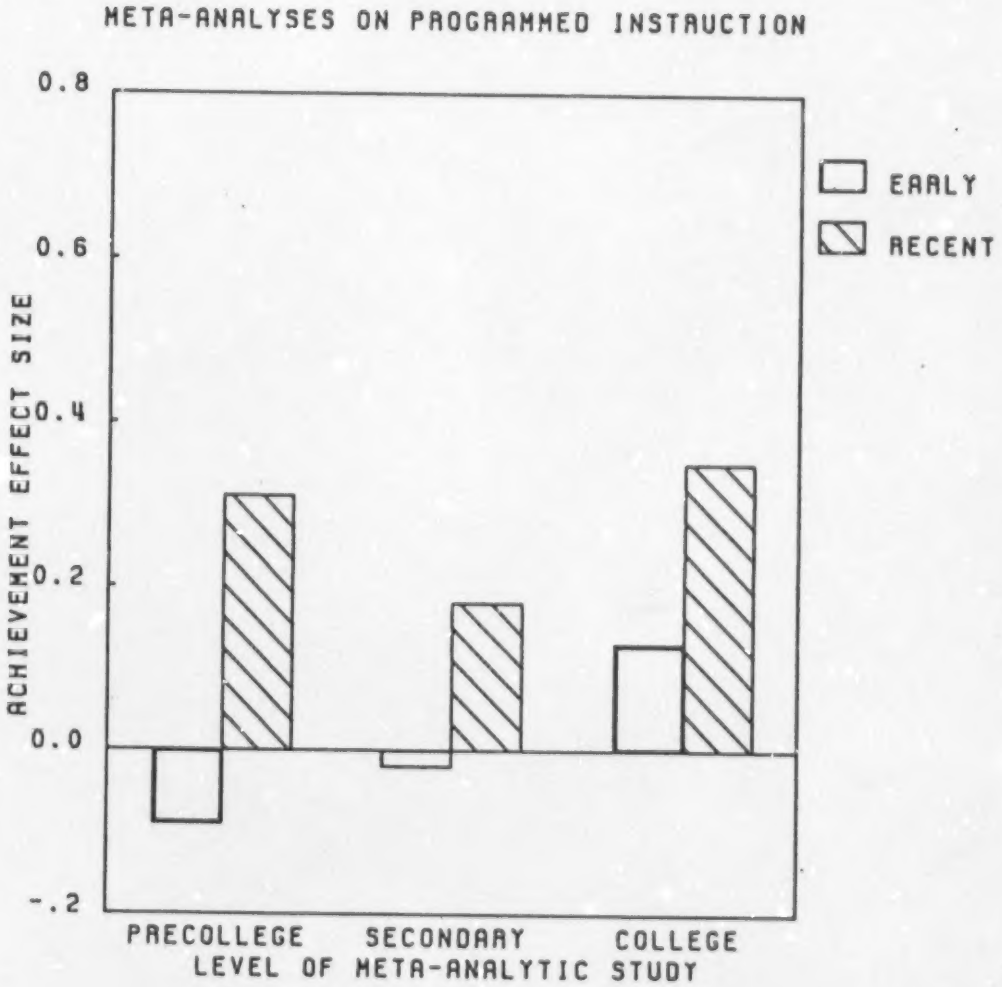
PRECOLLEGE
SECONDARY
COLLEGE
LEVEL OF META-ANALYTIC STUDY

Figure 1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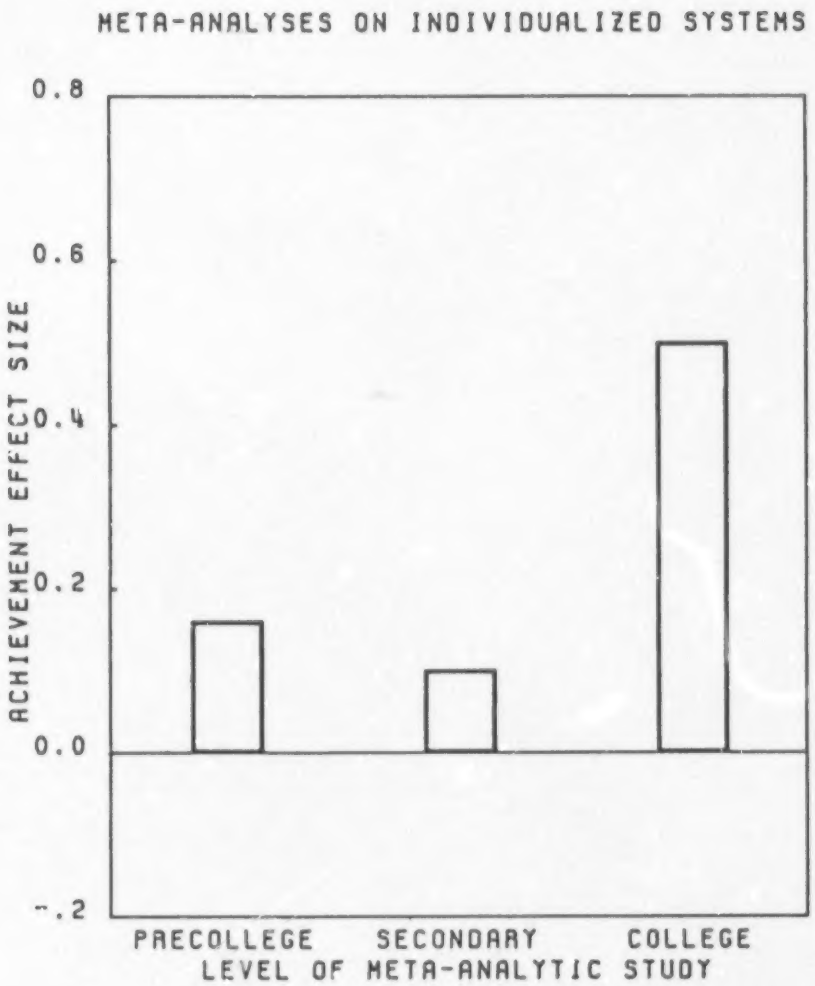
PRECOLLEGE
SECONDARY
COLLEGE
LEVEL OF META-ANALYTIC STUDY

Figure 2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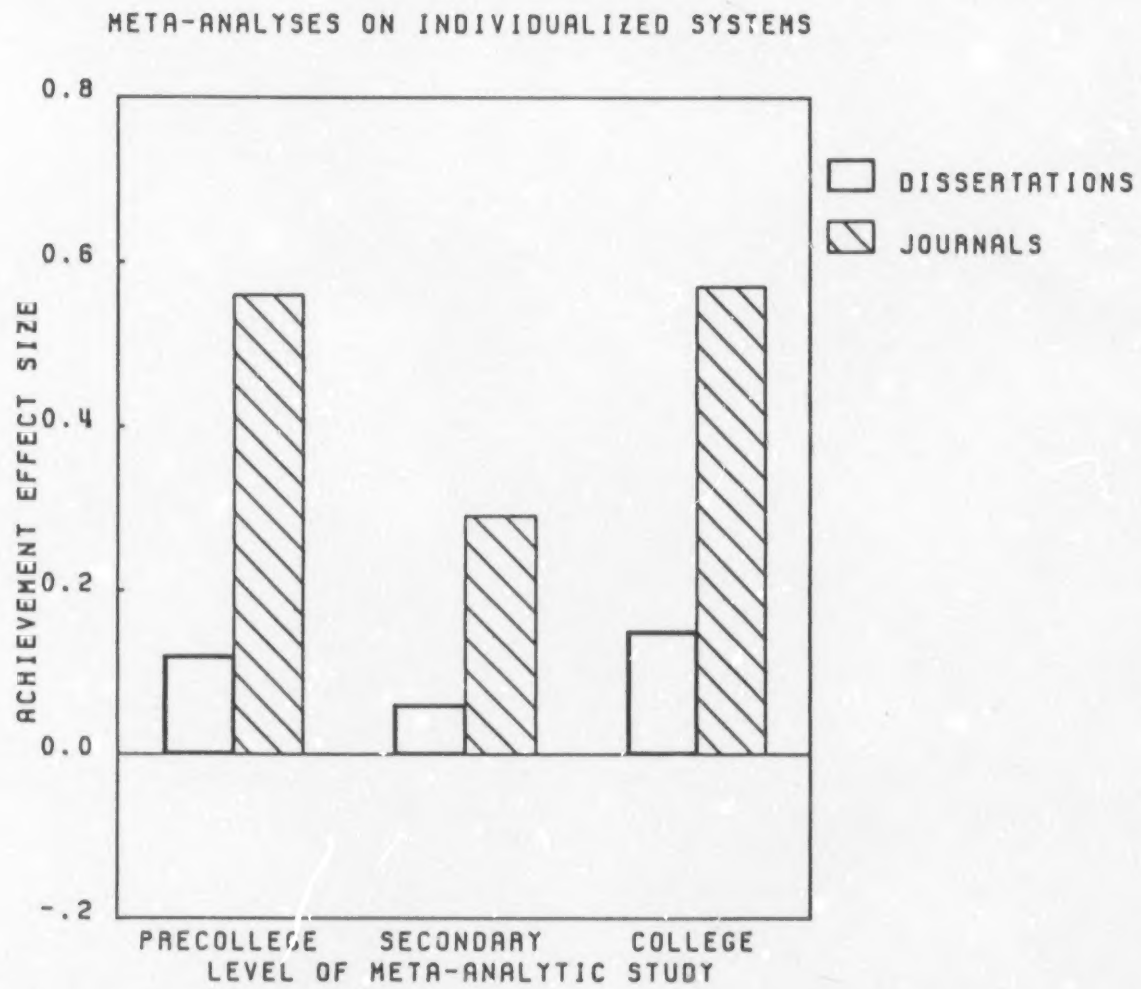
ACHIEVEMENT EFFECT SIZE
PRECOLLEGE
SECONDARY
COLLEGE
LEVEL OF META-ANALYTIC STUDY

Figure 3


META-ANALYSES ON INDIVIDUALIZED SYSTEMS
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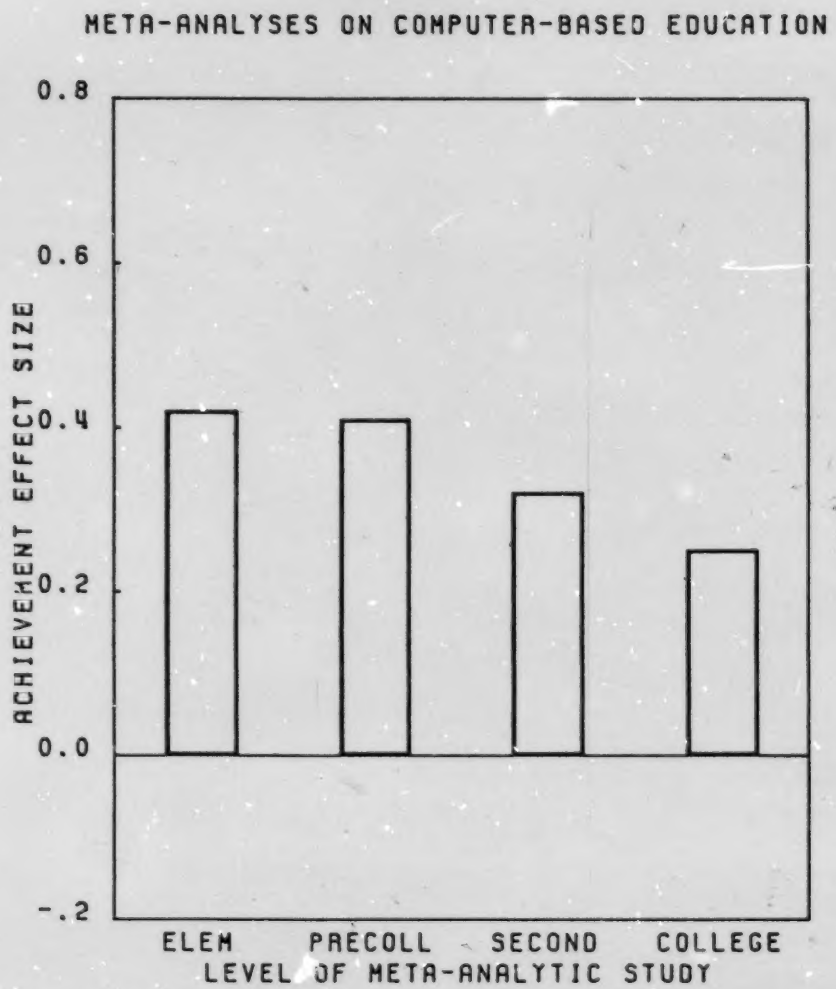
ACHIEVEMENT EFFECT SIZE
DISSERTATIONS
JOURNALS
PRECOLLEGE
SECONDARY
COLLEGE
LEVEL OF META-ANALYTIC STUDY

Figure 4


META-ANALYSES ON COMPUTER-BASED EDUCATION
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-.2
ACHIEVEMENT EFFECT SIZE
ELEM
PRECOLL
SECOND
COLLEGE
LEVEL OF META-ANALYTIC STUDY

Figure 5